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Dairy farming and biogas use in Rungwe district, South-west Tanzania: A study of opportunities and constraints

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Abstract

This study examined the opportunities and constraints of biogas use in Rungwe district, South-west Tanzania. Two hundred households with and without biogas facilities were selected randomly from four villages. Structured, semi-structured and open-ended discussion was used to gather information. Findings show a number of opportunities for biogas technology adoption including large numbers of indoor-fed cattle and inadequate firewood in the district, which has increased its cost of such commodity. Households generally spend an average of TShs. 20,656.50 per month or TShs. 247,876.8 per annum for energy. The demand for biogas (90%) among respondents is high and the energy policy as well as donor community favour the promotion of energy efficient technologies such as biogas. Constraints encountered in establishing biogas plants were found to include unaffordability (75%) and water scarcity. Also there is inadequate expertise where some of the biogas plants have been poorly constructed leading to ineffective performance. There is also a small proportion of the respondents who admitted that they had heard nothing about biogas technology. It is being suggested that credit should be available as well as developing affordable biodigestors. Communal biogas should be encouraged to reduce the cost per unit and the government should undertake the improvement of water services.

Keywords: Biogas technology; Rungwe district; Tanzania; Developing countries

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1. Introduction

1.1. The study area

This study presents the opportunities and constraints of biogas use in Rungwe district, South-west Tanzania. Firewood is the main source of cooking energy in the district, and the average firewood energy requirements is 600,000 m^3; while the capability is to supply 400,000 m^3 [1], making a deficit of 200,000 m^3. High demand of firewood has resulted into fast diminishing of forest reserves. The district has little "natural" vegetation which varies from upper montane forest at higher elevations to wet woodland (Miombo) at lower elevations. Forestry reserve accounts for 43,749.9 ha and other forests about 65,813 ha [1]. In recent years, much of this natural vegetation has been cleared/transformed for agriculture, habitation and firewood. Most of the remaining natural vegetation is found in government forest reserves and in locally protected areas, though even these areas have been subjected to varying degrees of people driven disturbances [2].

While deforestation is taking place at a fast rate, the district is one of the areas in the country with a large population of smallholders' stall-fed cattle. The district has 74,450 households and almost half of the households keep some cattle or pigs in their homestead with an average of between 2 and 6 cattle. There are about 52,036 indigenous cattle and 26,137 improved dairy cows [1]. Keeping dairy cows contributes positively to poverty

alleviation through provision of income, nutrition and food. Cattle keeping also contributes positively to the environment through the use of manure. However, cow dung could have been used more efficiently if it were first converted into biogas. Biogas technology could alleviate many pressing problems in the district, such as energy shortages, low agricultural productivity, and poor public health [3]. Despite the biogas promotion programmes in the two districts of Mbozi and Rungwe, there has been little impact on people's adoption of the technology. This study investigates the opportunities and constraints towards biogas adoption in the district. Findings from this study will provide inputs for policies and interventions.

1.2. Biogas use in developing countries

Biogas technology has been known for a long time, but in recent years the interest in it has significantly increased, especially due to the higher costs and the rapid depletion of fossil fuels as well as their environmental shortcomings [4]. There are about 16 million households worldwide that use small-scale biogas digesters.[1] Biogas technology is being successfully used in Asia in particular, but also in Latin America and some regions of West Africa. In China and India, biogas technology is particularly highly disseminated in smallholder farming. In India some 6 million tons of firewood were replaced by biogas in 1996 [5] while in China 7,000,000 biogas digesters contribute to the energy needs of about 4% of the Chinese population [6]. In these two countries, biogas technology today is part of standard practice.

The development of large-scale anaerobic digestion or biogas technology in Eastern Africa is still at an embryonic stage but the potential is promising [7].

1.3. The benefit of using biogas

The gas is useful as substitute fuel for firewood, dung, agricultural residues, petrol, diesel, and electricity, depending on the nature of the task, and local supply conditions and constraints [8], thus supplying energy for cooking and lighting. There is evidence that the use of biogas digesters leads to the obvious decrease of per capita energy consumption in rural families [9]. Biogas systems also provide a residue organic waste, after anaerobic digestion that has superior nutrient qualities over the usual organic fertilizer, cattle dung, as it is in the form of ammonia [10]. Eliminating drudgery of women, biogas reduces, if not removes, the daily task of firewood gathering, which can, in areas of scarcity, be the single most time consuming task of a woman's day [11].

1.4. Problems hindering biogas use

The most important problem hindering biogas technology in developing countries has been the cost of digester plants, difficulty in installing them and difficulty in getting spare parts [12]. A concrete digester plant installed for an average family in Vietnam varied from US$ 180 to 340 [13]. There is strong evidence that in most developing countries where biogas programmes have developed quickly it is because of substantial support from governments and aid agencies [14–16], and when the subsidies from governments

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[1] *Renewables 2005: Global Status Report*, a study by the Worldwatch Institute.

are reduced, the number of plants built each year falls dramatically [17–19]. Many developing countries such as Colombia, Ethiopia, Tanzania, Vietnam, Cambodia and Bangladesh promoted the low-cost biodigester technology aiming at reducing the production cost by using local materials and simplifying its installation and operation [20–23].

1.5. Biogas use in Tanzania

The problem of energy crisis continues to reverberate in many of the developing countries, and Tanzania is not an exception. The majority of families living in villages and small towns depend on wood as their domestic fuel by over 90%; this is because other conventional fuels such as kerosene, electricity and LPG are costly, unreliable or unavailable [24,25]. Surveys of energy in Tanzania suggest more frequent use of electric stoves for cooking in 1990 than presently [26]. Because of the serious environmental effects fuel-wood harvesting poses, other cheaper, environmentally friendly renewable energy sources such as biogas have been considered important [25]. Table 1 illustrates current household energy sources and utilization in Tanzania.

The history of biogas dissemination in Tanzania dates back to 1975 when the Small Industries Development Organization (SIDO) built 120 floating-drum plants in Arusha region.

In 1982, the newly founded Parastatal Organization Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) continued the dissemination of this technology in the region. About 1 year later, technical cooperation between Tanzania and the Federal Republic of Germany led to the introduction of the Biogas Extension Service (BES). CAMARTEC and the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) were in charge of implementing this project and the latter seconded an interdisciplinary team of social scientists, mechanical engineers and agriculturists to Tanzania [10].

In 1984–1985 household plants were offered with a digester volume of 8, 12 and 16 m^3, and in 1990 the programme comprised standardized plants of sizes 12, 16, 30 and 50 m^3 for households and institutions. The development work towards sustainable reliability and user friendliness resulted in extensive integration of biogas plants into the work routines of farmers. Over the period, CAMARTEC has been involved in training technicians in biogas plant construction. A ‘‘biogas unit’’ scheme was an integration of biogas plants, livestock housing with a concrete floor. CAMARTEC was also providing advice on the utilization

Table 1
Household energy sources and utilization

Type of energy used in household sector	Percentage of total household energy consumption	Purpose of energy used
Biomass fuels	97.7	Cooking, heating and lighting
Petroleum products	2.0	Kerosene for lighting and cooking
Electricity	0.3	Lighting, powering the radio and in a few cases cooking
Solar, biogas, wind	Insignificant	Lighting, cooking

Source: van Asperen [27].

of slurry, gas pipeline systems, burners and lamps; and women were specifically instructed on how to use and manage the plants.

Until 1989, only 200 units of biogas had been installed all over the country [10] but in 1992 this had increased to 600 plants. Privatization of the BES later on sent the costs for a biogas unit escalating from around TShs. 300,000 in 1989 to TShs. 700,000 currently.

Despite all the efforts, the biogas technology did not diffuse much to the rural poor communities. Some reasons for this poor diffusion of this technology in general have been suggested to include high installation and maintenance costs. The conventional units being built in the country were large and expensive, costing approximately US$ 1400 for one unit [28]. Furthermore, repair and maintenance requires highly skilled labour and most component parts, constructed mainly from concrete and steel, were far out of the financial reach of smallholder farmers. CAMARTEC's commercially oriented, and strictly standardized dissemination programme has been criticized by some critics, e.g. the Evangelical Lutheran Church of Tanzania (ELCT), who have claimed that the programme had not been adapted to Tanzanian conditions as it only served the rich farmers [10].

As a result, ELCT also came into the biogas technology business starting 1988. It coordinates, advices, organizes training of biogas craftsmen and deals with construction. The target group is made up of farmers with at least two herds of cattle. Chinese fixed-dome plants with conical fundaments are disseminated. The farmers receive 50% of the investment costs as credit depending on their socio-economic situation. To keep the investment costs low, the farmer families are included in the construction of plants. The costs for a $12\,m^3$ plant, for example, amount to an average of TShs. 100,000. Biogas accessories (lamps, stoves) are imported from India and China and are around half the price of those from CAMARTEC [10].

On the other hand, the Ministry of Water, Energy and Minerals in Dar es Salaam has been involved with biogas projects; its main activity has been to support the dissemination of biogas technology in the region of Dar es Salaam. It ensures training for private craftsmen, builds demonstration plants and it is in charge of monitoring and evaluation.

More recently, polythene tubular digesters have been promoted to reduce production cost by using local materials and simplifying installation and operation costs. The type of plastic needed for polythene is locally manufactured in Tanzania, maintenance and repair are simple, cheap, and do not require skilled labour and the cost of construction is low. A model promoted by Sustainable Rural Development (SURUDE) is a low-cost design suitable for poor farmers [29]. The material cost is about US$100. However, this type of biodigester has one major disadvantage—it can be easily sabotaged, i.e. torn out. This is because the plastic materials of the biodigestor are normally placed on the surface outside the house, therefore disposed without much protection.

1.6. Biogas technology in Rungwe district

Most of the biogas projects reviewed above in Tanzania were concentrated in the northern part of the country and Dar es Salaam, the commercial city of the country. This was partly due do big numbers of livestock in the area and the relatively high-income levels of the people.

Biogas technology in Rungwe district started in 1993 when one person adopted the technology. In 1996, 12 households got the service by contributing half of the cost; as this was a pilot project by Danish Volunteers. With the exception of the year 1996, adoption of

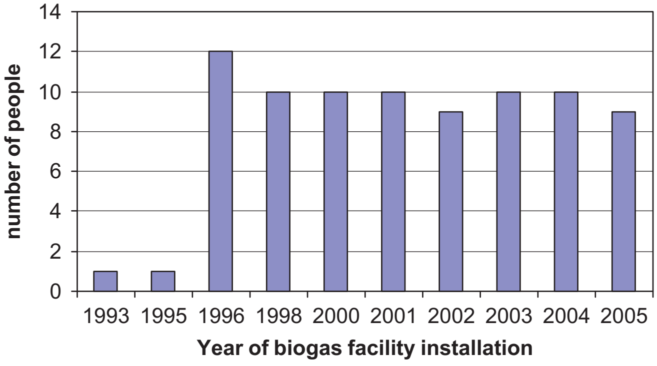

Fig. 1. Spread of biogas technology in Rungwe district.

the biogas technology has been low and more or less constant [30]. Currently, there are about 100 biogas plants in the district, an equivalent to only 0.13% of the total number of households (Fig. 1).

2. Methods

Both secondary and primary data were collected for this study. Secondary data were collected from different sources including Ministry of Water and Livestock Development, Ministry of Agriculture and Food Security, Ministry of Energy and Minerals, Ministry of Natural Resources and Tourism, Academic Institutions, Mbeya region, Rungwe district and respective villages, and published earlier work. Also NGOs that are involved in biogas technology (e.g. TaTEDO) were consulted for information.

Primary data were collected from 200 dairy keepers in the district; these included those with biogas facilities and those without biogas facilities. The sample villages were Isagilo, Mpuguso, Kyimo and Mpandapanda. These villages were selected from a total of 16 villagers with biogas facilities in the district. The choice of the villages was based on the following characteristics: the number of households with indoor-fed cows, where the biogas project started, and the number of households with biogas plants and villages with grid electricity services. For instance, Isagilo is a village where a biogas project (MS Project) started in 1996 and about 12 households acquired biogas facilities by contributing half of the cost. Mpandapanda is a village with a large population of indoor-fed dairy cows but with a limited number of biogas adopters. Kyimo is a village with a large number of dairy cows and has access to grid electricity services while Mpuguso is a village with a limited number of biogas and a limited number of dairy keepers. Households in these four villages were stratified into those with biogas plants and those without. Given the limited number of households with biogas facilities, the selection of the households within the stratum was purposive depending on their willingness to participate in the interview but it was random for those without biogas facilities. Twenty households (57.1%) out of 35 with biogas facilities in the four selected villages were selected for interviews while it was 180 from those without biogas. Table 2 provides the sample size per village.

Table 2
Village characteristics and sample size

Village	Characteristics	HH with biogas	HH with biogas selected for interview	HH without biogas selected for interview (10%)	Total sample
Isagilo	MS Biogas project started in 1996 and 12 HH installed biogas plants at half price	18	11	40	51
Kyimo	Large population of dairy cows and have electricity services	7	3	60	63
Mpandapanda	Large population of dairy cattle but limited number of biogas users	6	4	50	54
Mpuguso	Limited number of biogas adopters and dairy keepers	4	2	30	32
Total		35	20	180	200

3. Results and discussion

3.1. Opportunities for biogas use in Tanzania

3.1.1. Availability of a large number of indoor-fed dairy cows

Rungwe is one of the districts in Mbeya region with a large number of indoor-fed cattle; and dairy keeping in the district dates back to 1970s when different international organizations introduced dairy projects in Mbeya region. These included the Heifer International Project (HIP), DANIDA and Swiss Agencies. These programmes were providing dairy cattle to smallholder farmers on a method called "Heifer-in-Trust" scheme under which a farmer was loaned an in-calf heifer, and agreed to give the first two female calves to other farmers. By this way, most people in Rungwe district started keeping dairy cows. The Uyole Agricultural Centre was coordinating most of these activities. A report by Maganga and Matumla [31] indicates that the former Uyole Agricultural Centre has pioneered dairy development in the area by distributing dairy animals to small-scale producers since mid-1970s. The sale of breeding stock to small-scale farmers accounted for 93.9% of sold cows, the remainder going to large-scale farms. Livestock research department at the Ministry of Agriculture, Research and Training Institute (MARTI-Uyole) has continued to carry out problem-oriented research programmes geared towards solving problems hindering increased production in the dairy sector [32]. MARTI-Uyole has also continued to supply the livestock sector with subject matter specialists to serve with the Extension Department of the Ministry of Livestock Development including privately owned farms. To complement these efforts, short courses were conducted for both farmers and extension agents in the zone.

There is also a good number of indoor-fed indigenous cattle in the district; this is because, culturally, cattle are important for dowry payment and prestige. As a result, many families keep cattle in homes. The district has about 52,036 indigenous cattle and 26,137 improved dairy cows. Many also keep pigs and goats. For proper functioning, the digester requires excreta from one to two cows, five to eight pigs or four able-bodied people on a daily basis.[2] The district is also an agricultural intensive producer and its by-products could be utilized for biogas generation.

3.1.2. Shortage of firewood

Rungwe district has a total area of 2211 km^2 of which 75% is arable land [33]. Of the remaining area, 44.5 km^2 is covered by forest while 498.3 km^2 is either mountainous or residential.

The district is one of the densely populated districts in Tanzania [34] with a population of 307,270, which is equivalent to 139 persons per square kilometre. The district has little natural vegetation which varies from upper montane forest at higher elevations to wet woodland (Miombo) at lower elevations. Forestry reserve accounts for 43,749.9 ha and other forests about 65,813 ha [1]. In recent years, much of this natural vegetation has been cleared/transformed for agriculture, for habitation, and firewood. Most of the remaining natural vegetation is found in government forest reserves and in locally protected areas, though even these areas have been subjected to varying degrees of people driven disturbances.

Firewood is the main source of cooking energy, which has resulted into fast diminishing of forest reserves. Average energy requirements in the district is 600,000 m^3, while the districts capability is to supply 400,000 m^3 [1] making a deficit of 200,000 m^3. Scarcity of firewood has increased its cost in terms of purchasing price and time for collecting.

3.1.3. National energy policy

Domestic energy demand in Tanzania has been rising rapidly in recent years because of population growth. Wood accounts for 90% of the total energy used in Tanzania. While the supply of firewood is dwindling, demand is rapidly increasing. Households consume about 97% of wood energy mostly for cooking [35].

The overall policy goal for the energy sector of 1992 and its revised version of 2000 is to meet the energy needs of Tanzanians through a diverse range of strategies. The key policy objectives are to increase access to affordable and reliable energy services to meet the basic needs of the poor, stimulate productive capacity and to meet energy needs for community services such as schools, clinics, and water supply facilities.

In the power sub-sector, a number of technological options have been proposed for implementation including developing renewable energy sources such as hydro, wind, biogas and solar energy. The Government in collaboration with donors have been funding most of the biogas projects in the country in institutions such as schools and health centres and households.

3.1.4. Environmental benefits

The increasing awareness worldwide and the concern about the environmental impacts of fossil fuels coupled with ever increasing oil prices have lent enormous weight to a switch

[2]Africa-Tanzania 2.

to renewable energy sources [36]. Renewable energy sources can serve us indefinitely with minimal environmental impacts compared with fossil and nuclear fuels [37]. Since it also uses cow dung that would otherwise have degraded, further greenhouse gas emissions are avoided. A study by the Institute of Resource Assessment, University of Dar es Salaam, in 2005, shows that there was a reduction of firewood consumption from 700 to 145 m^3 for Lomwe Secondary School following the adoption of biogas technology which meant a reduction from 253.9 to 53.8 tonnes (a reduction of 78.9%) of CO_2 annually [38]. Firewood energy saved annually by implementing this project is approximately 6.7 Terra Joules (TJ).

Locally reduced deforestation helps to preserve forests and all of the services they provide, such as biodiversity and maintenance of water quality. Where biogas projects are from biolatrine, they improve the local environment through improved hygiene, resulting from the use of permanent toilets [39].

3.1.5. Impact of biogas on poverty alleviation

Biogas production integrated with cattle raising and farming provide a reliable source of cleaner fuel as well as increased income and employment opportunities. Such a system will facilitate the use of the effluent to increase crop yield and help to minimize inputs, thus reducing cost for crop production and ultimately leading to a higher income [39]. Reduced use of kerosene and wood for cooking and/or lighting improves air quality in the home, decreasing the incidence of respiratory and eye problems with better environmental conditions, less smell, fewer flies and cleaner wastewater [12,40]. Relief to women and children through use of biogas is achieved in two ways: one, biogas removes the smoke nuisance usually accompanied by use of firewood; and secondly, it has been reported that men participate more in household duties as the work becomes easier [41]. In cases where women had to walk long distances in search of firewood, use of biogas has been an obvious relief. The expenses for the biogas plant are paid back within 5–11 months [12,39].

The sale of milk in Tanzania generates significant income thereby increasing the family's income. Income from the sale of milk goes towards school fees for children, improved housing, clothing and equipment (such as bicycles). In addition, a large percentage of dairy farmers use hired labour therefore increased incorporation of cattle into farming and installation of biogas increases employment opportunities. The production of biogas also produces slurry that is very effective as fertilizer. Such fertilizer also helps to maintain soil quality over time, thereby improving crop yields.

3.1.6. Cost of firewood

Findings show that the distance to firewood sources is about 2.25 km and women spend between 3 and 4 h a day collecting firewood in the district, most people using firewood from their own trees, as communal land is very limited.

People with installed biogas facilities have saved cost and time from firewood, and the saved time is used for other economic activities as well as leisure. Also there is a significant reduction of cost for fuel energy for the households with biogas facilities—findings from the field show that firewood consumption by households with biogas plants has been reduced from 5.7 bundles per week to only one bundle. They have also reduced buying about 1.6 bags of charcoal per month to insignificant quantity. In addition, they have saved about 5 l of kerosene for cooking and lighting, per month (Table 3).

The amount of firewood reduced by using biogas is equivalent to financial saving of TShs. 6000 from purchasing firewood, TShs. 15,000 from charcoal and about TShs. 5656.4

Table 3
Amount of fuel wood reduced by using biogas

	Before biogas installation	After biogas installation	Overall
Firewood bundles per month	5.7 (4.3)	1.0 (1.4)	***
Time of firewood collection for those who use only biogas (h)	3.9 (3.2)	0	
Charcoal (bags)	1.6 (1.8)	0.2	
Kerosene cost (l)	5	0	

Figures in brackets indicate standard deviation.
***Significant at $P<1\%$.

Table 4
Financial saving (TShs.) per month

	Before biogas installation	After biogas installation	Overall
Firewood	7000 (3452.6)	1000 (967)	***
Charcoal	8000 (5632)	0	
Kerosene cost	5656.4 (6172.2)	0	
Total	20,656.4	1000	

***Significant at $P<1\%$.

from buying kerosene. This makes a total saving of TShs. 20,656.4 per month or TShs. 247,876.8 per annum. Such a saving is significant and is used for paying school fees, buying uniform and books for children, and paying for health services, etc. About 36% of the Tanzanian population is living below the poverty line of one dollar a day [42] (Table 4).

3.2. Factors constraining biogas technology adoption

3.2.1. Cost of constructing a biogas plant

The main factors constraining biogas technology adoption is cost. Over 65% of the respondents mentioned high cost as the main constraint. Findings from the field show that the average cost per plant constructed is TShs. 565,000 (US$ 435)[3] with a range from TShs. 400,000 to 700,000 (US$ 538). Most of the farms with biodigesters belonged to the medium income group [43]. Wider use of biogas systems required reduced construction costs and quantification and valuation of direct and indirect costs and benefits [44]. Brown [44] concludes that biogas technology depends on three main constraining factors—economic, technical and socio-cultural. Although, there has been efforts to manufacture low-cost biodigester in the country, its production capacity and insemination is still low.

3.2.2. Inadequate water availability

Less than 40% of the population in Tanzania is directly connected to the water supply network. Water in some of the villages under study is obtained very far and this is time consuming. At least 60 l of water are required for a cow per day as well as 60 l to put into

[3] 1$ = TShs. 1280.

the biodigester [28]. During the study, five households revealed that their biogas plants had stopped working due to lack of water.

3.2.3. Inadequate expertise

Inadequate expertise for construction and maintenance of biogas plants is another constraint hindering biogas technology in the district. Competent experts are only two in the district and are residing, one in the district headquarters and another in one of the villages. Chand and Murthy [45] identified 50% of 1670 plants in the study as incapable of ever being made functional. Further, when complications have arisen in the functioning of plants, a common complaint articulated is that there is lack of technical support [46]. A study by Polprasert et al. [47] revealed that a major operational problem was excessive scum accumulation in the digester due to low specific gravity of the plant matter substrates. Future R&D in biogas technology requires more technological efforts and building capacities in biogas construction [3].

4. Conclusion and recommendations

4.1. Conclusion

There are several opportunities for biogas adoption in the district, including the large number of households with indoor-fed cattle and/or pigs, and high scarcity of firewood which has raised the cost of firewood. The energy policy as well as global energy directions emphasize renewable bioenergy for sustainable development. Adoption of biogas also has the potential to create employment in the district and countrywide. Furthermore, many households are willing to have biogas facilities in their homes but what seem to be the hitch is the ability to meet the cost. The cost of TShs. 400,000–700,000 is beyond the reach of many people in the district. Also expertise is very limited and water availability is a problem in some villages.

4.2. Recommendations

The high cost of buying a biodigestor could be minimized through producing low-cost and affordable biodigesters. Although subsidies could reduce the cost of biogas and therefore stimulate more incentive to adopt the technology, subsidies are discouraged due to associated inefficiencies. Rather, credit in terms of cash or materials should be made available in the district.

Training should be conducted in the district to raise the level of expertise but also to achieve widespread dissemination of biogas technology awareness. Water supply should also be improved by the government.

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